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ENHANCEMENT OF DIRECTIONAL AMBIGUITY REMOVAL SKILL IN SCATTEROMETER DATA PROCESSING USING PLANETARY BOUNDARY LAYER MODELS

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1. INTRODUCTION

For an advancement of atmospheric and oceanic studies, observation data with spatially and temporally high resolution are crucial. Among the data are surface winds over ocean that are provided by active microwave radars such as scatterometers on satellites.

Ocean vector winds can be retrieved from microwave backscattering coefficients for ocean surface waves. The baseline data processing algorithm for NASA scatterometers is based on techniques utilizing a geophysical model function and a maximum likelihood estimation (see Chi and Li, 1988, for a review of selected techniques).

The configuration of the current scatterometer radar systems inevitably produces multiple wind vector solutions differing widely in directions (a.k.a. ambiguities) and the current data processing system at JPL uses a median filter to choose vectors consistent with the surrounding wind vector field (Shaffer et al., 1991).

The current data processing algorithm, however, also utilizes wind directional information from numerical weather prediction (NWP) models to initialize the median filter algorithm. This so-called "NWP nudging" method is very effective, but inevitably relies on external input, i.e., NWP model product. The accuracy of the wind vector selection by this technique thus depends strongly on that of NWP products, raising some concerns regarding the performance. For example, if an NWP system fails to accurately forecast a hurricane's location, potentially more accurate measurements by a scatterometer may erroneously be discarded by the NWP nudging.

Among the efforts being made at JPL to improve the so-called "ambiguity removal problem" is to adopt a new approach which uses physically-based models such as planetary boundary layer (PBL) models.

2. METHOD AND TOOLS

Pressure field near the surface is more coherent over large scales than corresponding wind vector field and thus complements the wind field in describing smaller-scale systems (Hsu and Liu, 1996). Moreover, pressure is scalar whereas wind is vector. Assuming that smaller-scale features are most likely noise rather than signal, these statements imply that noise in pressure field, unlike that in corresponding wind field, can be reduced by spatially smoothing the pressure field or by applying other available noise filtering technique.

The methodology used for this study is as follows: A first-guess field is obtained from the retrieved scatterometer wind vectors as selected by the median filter initialized with the highest-likelihood wind vectors. This wind field is then used to derive a pressure field by using an inverted PBL model. Next, after smoothing the pressure field to filter out small-scale noise, a wind field is re-derived by using a PBL model. This improved wind information is then used to re-initialize the scatterometer ambiguity removal process.

For deriving pressure field from winds, a version of the two-layer similarity model of Brown and Liu (1982) is used, whereas for deriving winds from pressure the equations governing the Ekman layer model of Yu (1987) are used. Some model parameters have been either simplified or adjusted to minimize the inconsistency between the two systems of equations with different assumptions.

3. CASE STUDY WITH QUIKSCAT DATA

A new NASA scatterometer "SeaWinds on QuikSCAT" was launched on 19 June 1999 and is currently in stable orbit. Preliminary data from QuikSCAT, which are under calibration and validation, were used for this study. Several hurricanes are selected for case studies. The case discussed in this paper is Hurricane "Eugene" detected around 3 UTC on 9 Aug. 1999 located in eastern Pacific (135W ~ 120W; 5N ~ 20N). A high resolution ($1^\circ \times 1^\circ$) ECMWF (European Center for Medium-Range Weather Forecasting) 10m wind is selected as "true wind" for a comparison with the observed wind.

Figure 1 shows the wind field used to "hedge" the scatterometer measurements, superposed by corresponding pressure field. The source is an NCEP (National Centers for Environmental Prediction) 1000mb 3-hr forecast field with 2.5° resolution. Figure 2 is the scatterometer winds nudged by the NCEP winds. Figure 3 shows the nudging field obtained from scatterometer measurements with the aid of the PBL models; initial winds are selected by the median filter using the most-likely wind vector and are converted to pressure field to which a nine-point spatial smoother is applied; and the pressure is converted back to winds. Figure 4 is the scatterometer winds nudged by this PBL model-generated nudging field. For verification, a 1° ECMWF wind field at 10m elevation is shown in Fig. 5 as independent higher resolution winds.

4. DISCUSSION

The main purpose of this study is to generate a wind field for nudging the scatterometer winds, i.e., for removing the directional ambiguities of scatterometer measurements, thereby avoiding the dependence of the wind retrieval processing system on external data, in this case, an NWP product.

The nudging field based on the NWP product (Fig. 1) does not have a closed cyclonic system which is seen in the higher resolution NWP field (Fig. 5) and other satellite cloud images (not shown). On the other hand, the nudging field made from the scatterometer measurements with the aid of PBL models have a closed cyclonic system (Fig. 3).

The pressure pattern of the 1° verification NWP field (Fig. 5) shows a front-like system extending to southwest direction from the center. In this area, the low-resolution 2.5° nudging field (Fig. 1) has a group of reversed vectors that contribute to incorrect nudging of the winds. A closer look at the pressure fields show, however, that the PBL model-derived nudging field shows some difference in the pattern near the edges of the swath, leading to some discrepancy in wind direction compared with the 1° NWP wind. This is a current limitation of the PBL model nudging approach applied to a limited region, i.e., a region with lateral boundaries where the input winds are extrapolated.

A comparison of the wind field nudged by the 2.5° NWP field (Fig. 2) and that by the PBL model-derived field (Fig. 4) reveals a general agreement. Near the center of the hurricane, however, the NWP nudged winds show vectors that are quite dissimilar to the 1° NWP field (Fig. 5), whereas the PBL model-nudged winds show vectors that do not conform to the 1° NWP field near the edges of the swath. It should be noted here, however, that the 1° NWP field should not be viewed as absolute truth. For a robust verification, actual wind observations, such as buoy data, are required.

Through the case discussed here and other cases, it is found that the ambiguity removal skill can be improved when the new technique utilizing physical directional information obtained from PBL models is used properly in conjunction with the median filter. We are also developing methods that alleviate the problems noted in regard to the application of our "PBL nudging scheme", which will be reported at the conference and elsewhere.

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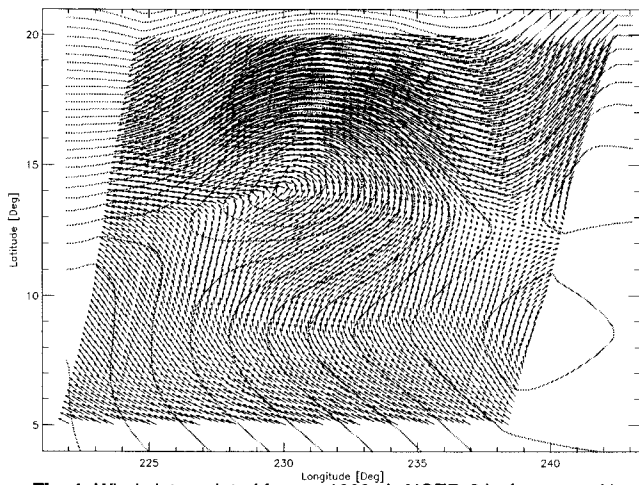


Fig. 1. Winds interpolated from a 1000mb NCEP 3-hr forecast with 2.5° resolution to be used for nudging (arrows) and corresponding pressure derived from the winds by using a PBL model (contours) showing Hurricane Eugene at 3 UTC on 9 Aug. 1999. The longitudinal boundaries are the edges of the satellite swath.

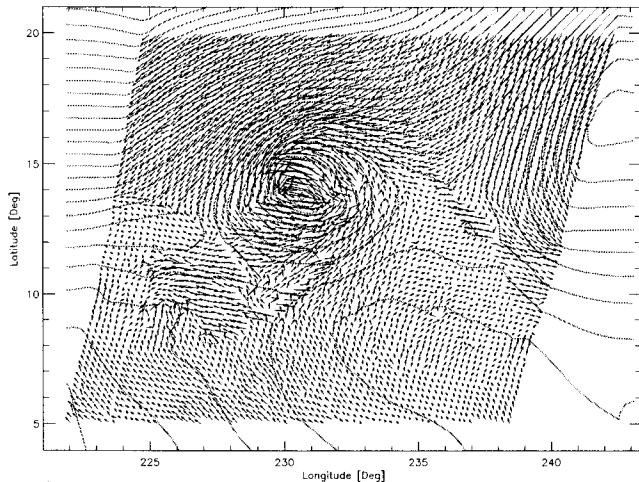


Fig. 2. Winds showing Hurricane Eugene as observed from NASA scatterometer "SeaWinds on QuikSCAT", which are nudged by the NCEP winds shown in Fig. 1 (arrows) and corresponding pressure derived from the winds by using a PBL model (contours).

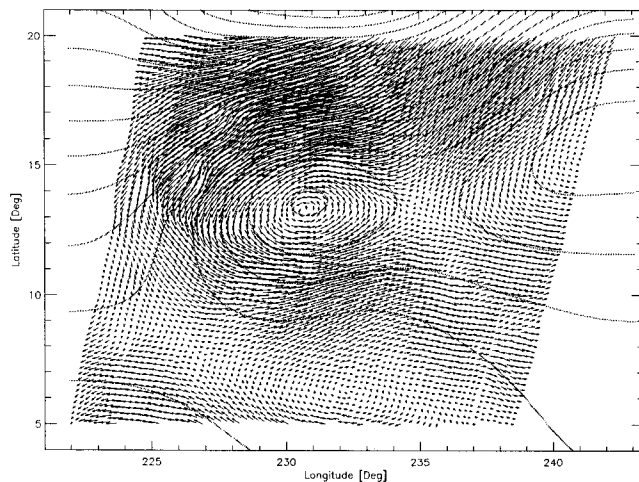


Fig. 3. Winds interpolated from scatterometer measurements processed by the PBL models to be used for nudging (arrows) and corresponding pressure (contours).

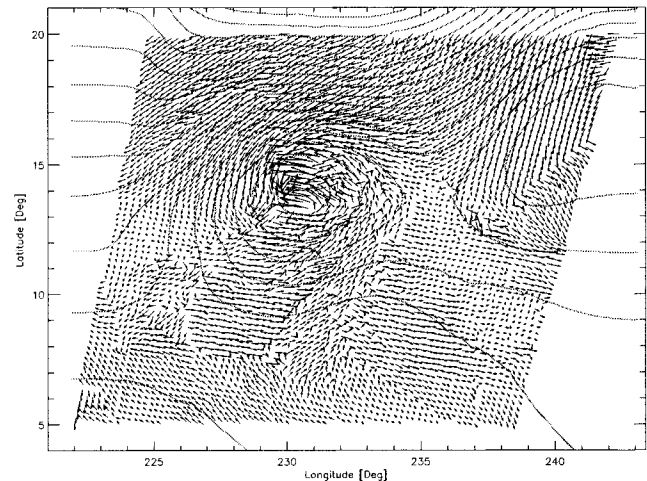


Fig. 4. Scatterometer winds (and corresponding pressure) nudged by the PBL model-processed nudging winds shown in Fig. 3.

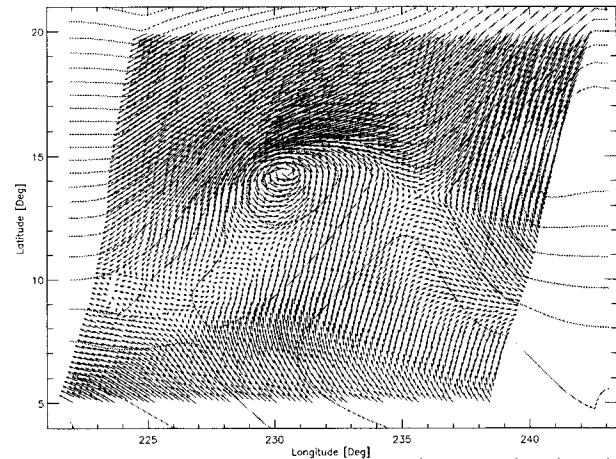


Fig. 5. ECMWF 1° analysis winds (arrows) at 10m elevation with corresponding pressure (contours).

5. ACKNOWLEDGMENTS

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